Internal Wave Strength Estimation from the ATOC95 Acoustic Transmissions

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LONG-TERM GOAL

My long term goals are to provide the navy with robust algorithms for measuring internal wave fluctuations and for compensating for their effects in passive submarine detection and tracking. The oceanography community is actively working in measuring internal waves with acoustic and non-acoustic methods and the navy surveillance community has neglected the effect of internal wave scattering in their present models.

OBJECTIVES

The ATOC95 experiment transmitted broadband signals centered at 75 Hz from Pioneer Seamount, off the coast of California, to a vertical line array (VLA) near Hawaii. The combination of VLA and long range propagation provides the opportunity to perform acoustic mode based internal wave tomography. The strength of the internal wave field is an important oceanographic parameter to the US Navy because of its effect upon acoustic propagation. The range/frequency limits of coherent localization are dramatically affected by internal wave scattering especially at higher frequencies. The final section of this report is work that was presented to the SSBN security program in support of their passive SSBN threat assessment study. It is work that directly benefits from the current research funded by ONR.

APPROACH

The recorded acoustical signal is pressure as a function of arrival time and depth. Previous work has involved the inter-comparison of the phase and travel time wander of the early arriving acoustic energy with simulations. In this work, we examine the late arriving energy, corresponding to the low angle propagating energy. These lower order acoustic modes are the most heavily impacted by internal wave induced mode coupling. Each arrival is mode filtered and the statistics of the mode arrivals are tabulated. The individual mode arrival time (centroid) and spread are then compared with calculated mode statistics from broadband PE modeling of the propagation path.

To do the internal wave inversion, a series of simulations have been performed. Five random phase realizations of internal waves using a Garrett-Munk spectrum were calculated. Broadband PE calculations using a Frequency Interpolation PE, where calculated with internal wave strengths of 0, 0.5, 1.0 1.5 and 2.0 times the standard reference level. This was done with two different bottom types near the source (sand and basalt.) This yields 21 simulations for each bottom type. To perform the inversion, the average spread of modes 1 through 25 was calculated as a function of internal-wave strength. Basalt is more strongly scattering so mode coupling that is a result of bottom interaction near

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the source yields larger spreads. There is uncertainty in the true bottom type. The internal wave inversion is done by comparing the spread of the data, for a particular reception, with the simulations.

WORK COMPLETED/RESULTS

We are now 2 months into a 6 month project. The data has been received from the Scripps Institute of Oceanography. It has been plotted and examined to determine receptions with no signal or poor signal to noise on a significant number of phones. The remaining set was mode filtered in the frequency domain. The first and second order statistics of the received modes (centroid and spread) have been calculated. With the spread providing the most insight into the energy level of the internal wave field, these results for the entire data set are presented here in figure 1.

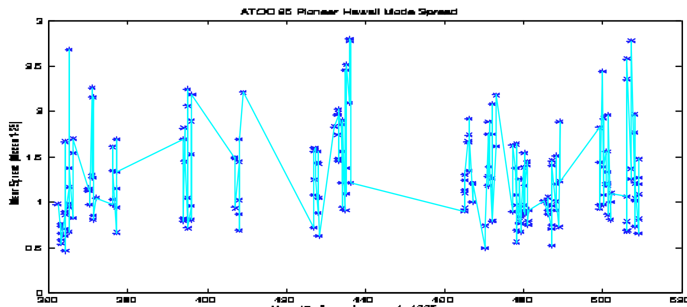

Figure 1: Mode 1-25 spreads for Pioneer-Hawaii ATOC transmission.

A seasonal fluctuation in the internal wave strength does not appear in this first look at the mode spreads of the received data. There are a few weeks that have significantly greater mode spreads than the previous weeks and weather this result is dependent upon the storm activity in the North East Pacific will be investigated. There does appear to be evidence for small-scale fluctuations of the mode spread and therefore internal wave strength. The relations between these fluctuations and internal tides is being evaluated. Another sensitivity which will be looked into is the dependence upon season of the mode inversion and the forward modeled PE calculations which the inversion is based upon. Once robustness of the inversion is determined, the effects of IW on range localization for the entire data set will be examined to conclude this work.

IMPACT/APPLICATION

The scattering of acoustic energy by internal waves is a topic of considerable research in the ocean acoustics community. Internal wave scattering is the limiting physics for coherent localization of distance sources using matched field processing. The breakdown of correlation from the range-independent solution is examined. The results are that range limits for coherent Matched Field Processing are set at 100, 250, 1000 and beyond 3000 km for the 150, 75, 30 and 10 Hz signals respectively.

To examine the breakdown of coherent signal caused by internal wave scattering, the vertically averaged correlation was calculated using :

$$C(\omega,r)=\frac{1}{N}\sum_{i=1}^{N}\int dz P_i^*(\omega,r,z)P_0(\omega,r,z)\Big/\left\{\int dz\left|P_i(z)\right|^2\int dz\left|P_0(z)\right|^2\right\} \qquad (1)$$

where N = 21 is the number of internal wave realizations used for each frequency. The correlation was calculated every km out to a range of 3000 km for a fully spanning vertical line array. The results for 4 frequencies are shown in figure 1. The source depth for these simulations was 100 m. As another measurement of internal wave scattering effects, the rms phase fluctuations where calculated for each position in range/depth. The depth averaged rms phase fluctuations are shown in figure 2 (b). Coherent MFP can be expected to work with correlations larger than 0.8 and rms phase fluctuations less the 0.6 (lambda/10). For a 100m source depth, this occurs at ranges of ~ 100, 250, 1000 and 3000 km for the frequencies 150, 75, 30 and 10 Hz.

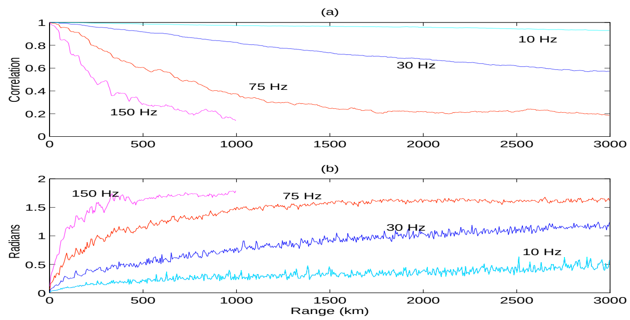

FIGURE 2: (a) Correlation between range independent and IW PE calculations. (b) Vertically averaged rms phase fluctuations as a function of range and frequency.

RELATED PROJECTS

1 – Internal wave strength determination using ray statistics of the ATOC 95 data set done by John Colosi (WHOI) and Stan Flatte (UCSC), work sponsored by ONR.

2 – Effects of internal waves scattering on submarine detectability using MFP for the SSBN Passive Threat Assessment Program. Work done by Kevin Heaney (SAIC) sponsored by Jim Griffin (N-87).

3 – Active internal wave measurements using the proposed EIGER 99 deep water test in the Gulf of Alaska. Work done by Kevin Heaney (SAIC), sponsored by Jim Griffin (N-87).

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Kevin D. Heaney, "Simultaneous inversion for source location and internal wave strength using long range ocean acoustic signals," in *Scripps Institution of Oceanography*. La Jolla: University of California, San Diego, 1997, pp. 350

John Colosi, Stanley Flatte, and Charles Bracher, "Internal-wave effects on 1000-km oceanic acoustic pulse propagation: Simulation and comparison with experiment," J. Acoust. Soc. Am, **96**, 452-468, (1994).